COX INSTRUMENTS
FLOW MEASUREMENT

Proven Performance for Over 50 Years

COX Series 220 Sonic Nozzles

GAS FLOW MEASUREMENT AND CONTROL

INTRODUCTION

Sonic flow nozzles are mass flow instruments designed for the accurate measurement and control of gas flow. The COX Instrument Series 220 Sonic Nozzles can handle flow from 0.04 to 10,000 standard cubic feet per minute. The internal design of the nozzle consists of a circular arc which leads to the minimum throat area. Tangent to the circular arc on the exhaust side is a conical diffuser section. Common applications of the sonic nozzle include use as a calibration standard, gas flow meter, flow controller and flow limiting device.

DESCRIPTION

Standard nozzles are sized according to the inlet pressure available to give continuous and overlapping flow ranges (see COX Series 220 Sonic Nozzle Graph on next page). Sizes range from a minimum throat diameter of eleven thousandths of an inch to a maximum of one inch. These nozzles may be purchased individually or in sets of seven or ten nozzles, which include the upstream and downstream flow straighteners. Taps are provided in the upstream flow straightener for pressure and temperature sensing. A pressure tap is provided in the downstream flow straightener to check for a critical ratio across the throat. The nozzles, as well as the flow straighteners, are available with AN-8, AN-16 or AN-32 flare tube fittings (NPT fittings available upon request), and are suitable for use up to 3000 psia inlet pressure.

ACCURACY

The COX Instrument Series 220 Sonic Nozzles are available with accuracies of ±3% or ± 0.5% of the reading. Un-calibrated nozzles will deliver the ±3% of reading accuracy using standard calculated data. The ±0.5% of reading calibration is available for all the nozzles at any given set of flow conditions. A complete set of data and a performance graph are supplied with each nozzle.

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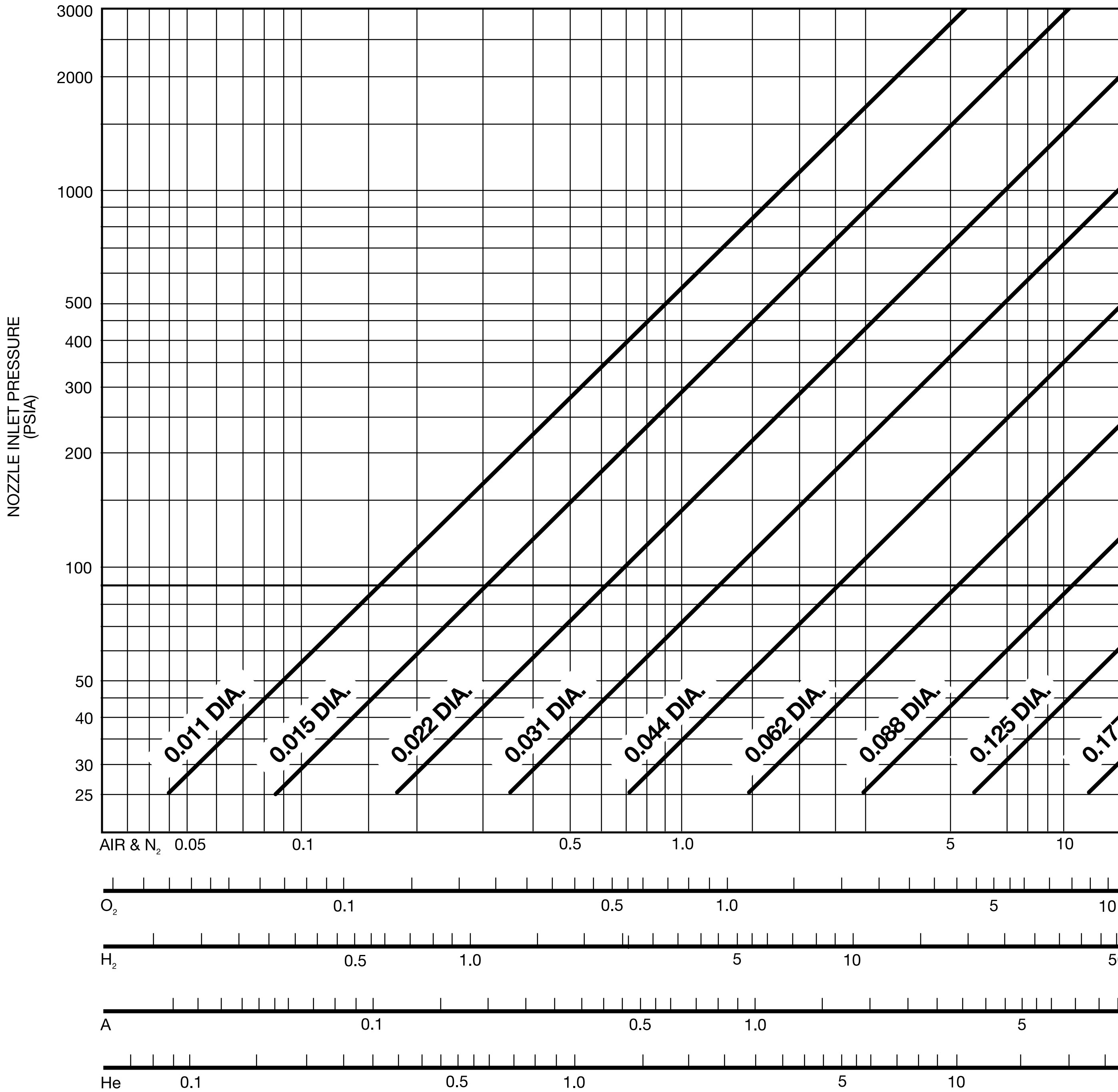
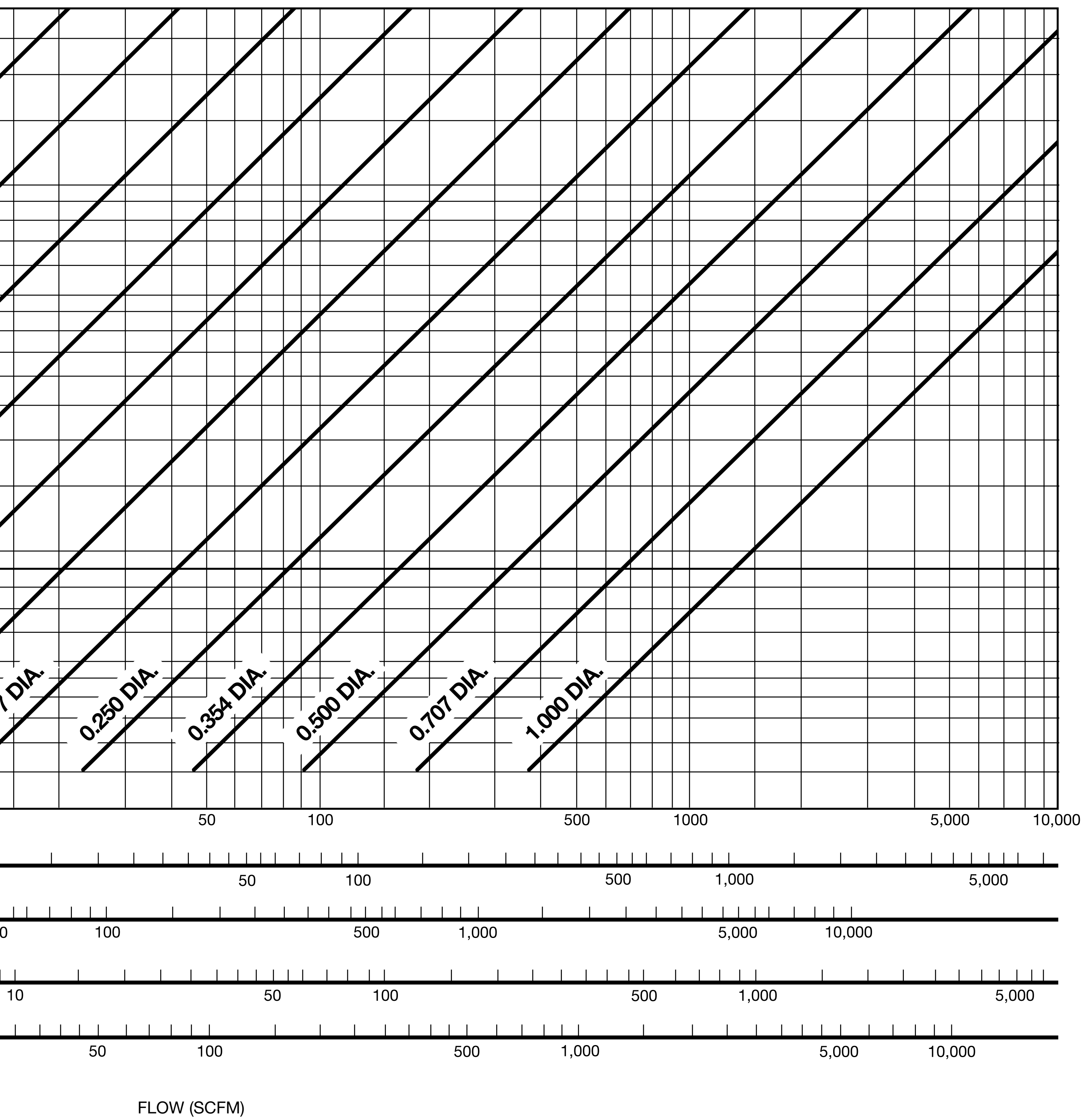
COX SERIES 220 SONIC NOZZLE SIZING GRAPH (TEMPERATURE = 70°F)




0.250 DIA.
0.354 DIA.
0.500 DIA.
0.707 DIA.
1.000 DIA.
50
100
500
1000
5,000
10,000
FLOW (SCFM)

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PRINCIPLE OF OPERATION

The sonic nozzle is similar to a subsonic variable head type flowmeter in that a constriction is present in the flowstream. As the gas flows through the converging section of the nozzle, the inlet pressure is converted to velocity, which reaches a maximum at the throat. When the fluid velocity reaches the speed of sound at the throat, the flow rate will vary linearly with the inlet pressure and will not be affected by downstream pressure fluctuations. The pressure drop across the nozzle must be sufficient to maintain sonic flow at the throat. Normally, sonic flow occurs when the downstream pressure is not greater than one-half the upstream pressure. The COX design improves this ratio so that sonic flow can be achieved in many applications when the downstream pressure is as much as three-quarters of the upstream pressure.

The determination of mass flow rate using the sonic nozzle requires only two measurements—the nozzle inlet absolute pressure and inlet absolute temperature. Therefore, the flow rate through the nozzle becomes highly predictable and is a function of the following relationship:

$$W = K\,C\,a\,F_i \left(\frac{F}{F_i}\right)\left(\frac{P_{IT}}{\sqrt{T_{IT}}}\right)$$

Where:

- W = Flow rate
- K = Constant—For unit conversion
- C = Discharge coefficient at sonic flow conditions
- a = Throat area
- P_{IT} = Inlet stagnation pressure
- T_{IT} = Inlet stagnation temperature, °R
- F_i = Sonic flow function of an ideal gas. Dependant on the type of gas.
- $\frac{F}{F_i}$ = Ratio of the real gas sonic flow function to the sonic flow function of its ideal gas counterpart. Dependant on the type of gas as well as the inlet stagnation temperature and inlet stagnation pressure.

For a particular nozzle and gas, this equation simplifies to:

$$W = \frac{K_I\ P_{IT}}{\sqrt{T_{IT}}}$$

Where:

- W = Flow rate
- K_I = Flow coefficient based on actual calibration
- P_{IT} = Inlet stagnation pressure
- T_{IT} = Inlet stagnation temperature, °R

SIZING INSTRUCTIONS

When determining the proper size of a sonic flow nozzle for gas flow applications where the temperature is standard condition (70ºF) and flow is given in SCFM, the nozzle is selected directly from the graph.However, when temperature is at other than 70ºF, corrected flow is approximated using the following formula, before selecting the nozzle from the graph.

- W_C = Corrected flow
- Wref = Desired flow
- T_2 abs = Operating temperature in degrees Rankin (T = °F + 460)

$$W_C = W_{ref}\sqrt{\frac{530}{T_{2\,abs}}}$$

When flow is given in units other than SCFM, convert to SCFM using the appropriate equation below:

$$W\ (SCFM) = \frac{W\ (pph)}{60\ (std.\ density)}$$

$$W\ (SCFM) = 36.05\ (acfm)\ \frac{P}{T}$$

$$W\ (SCFM) = \frac{W\ (ppm)}{(std.\ density)}$$

$$W\ (SCFM) = \frac{W\ (pps)\ 60}{(std.\ density)}$$

For more information, contact COX Instruments or your local COX Instruments representative.

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